RESEARCH CIRCULAR 261 OCTOBER 1980

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ACKNOWLEDGMENTS

This study was supported in part by Landmark, Inc., Columbus, Ohio. Appreciation is extended to Wayne Landmark, Smithville, Ohio; Ohio Ag Services Inc.; the Wayne County Cooperative Extension Service; and especially to the dairymen who cooperated in this study.

AGDEX 410/55-64 10-80-2.5M

Effects of High Fat Diets on Milk and Fat Production in Commercial Dairy Herds

A. J. HEINRICHS, D. L. PALMQUIST, and THOMAS E. NOYES[1]

SUMMARY

A high-fat protein supplement was incorporated into complete mixed diets of lactating dairy cows in eight commercial dairy herds using group fed animals in free stall housing. The fat content of the total dietary dry matter was increased from approximately 3% to approximately 6%.

When the high-fat diets were fed, daily milk production of the high producing Holstein cows increased 1.4 kg/day while milk fat percent decreased 0.2 percentage unit. Fat-corrected milk of cows fed the high-fat diets increased 0.7 kg/day. Although there was no change in daily milk production in the low producing Holstein cows, they decreased in milk fat percent when fed the high-fat diet. Jersey cows responded similarly except for decreased milk production in the low production group fed high fat. Lower milk fat percent was attributed to decreased fiber content of the diets when the high-fat supplement was fed. Milk protein percent was not changed by feeding the high-fat diet.

INTRODUCTION

Milk production of dairy cows is often limited in early lactation by their ability to consume nutrients and utilize body stores of protein and energy (5).

Traditionally, the energy level of the diet has been increased by increasing the amount of concentrate fed, resulting in an increased ratio of concentrate to forage fed. This change in concentrate to forage ratio causes a depression in milk fat yield, reduced digestibility of feeds, and a reduced dry matter intake when excess grain is fed (6).

The usefulness of increased fat feeding to minimize problems of feeding excess concentrates has been demonstratd by Palmquist and Conrad (10). They reported that feeding diets containing 3.3% hydrolyzed fat increased production of 4% fat-corrected milk by dairy cows in early lactation. The increases were due to a significantly higher production of milk fat by cows fed the added fat. This increase in milk fat was attributed to a higher fiber content of the diet containing added fat.

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They concluded that 7% to 8% fat can be included in the rations of lactating cows, increasing the energy intake and the forage to concentrate ratio to help maintain milk fat percent, without negative effects on digestibility.

Others have also shown increased milk production when added fat was fed. Macleod *et al.* (7) reported that adding protected tallow to the rations of dairy cows in early lactation increased the yield of 4% fat-corrected milk. Stull *et al.* (12) reported a significant increase in milk production of cows in mid-lactation when they were fed rations containing 7% tallow. Mattos *et al.* (8) reported a significant increase in milk and fat production when feeding protected or unprotected full-fat soy-flour.

As the trials of Palmquist and Conrad were limited in duration and cow numbers, a feeding trial was initiated to further examine the application of high-fat diets in commercial dairy herds.

METHODS AND MATERIALS

Eight commercial dairy herds (six Holstein and two Jersey) in Wayne County, Ohio, were selected using the following criteria: 1) an official Dairy Herd Improvement testing program was used; 2) cows were housed in free stalls, divided into at least two production groups (a high group of greater than 40-50 lb of milk per day); 3) a complete mixed feeding system was used; and 4) no recognized major problems concerning nutrition or other managerial practices existed that could affect or bias the results.

Herds with minimum individual cow care were selected to reduce personal bias on the part of the dairymen (1). The trial was conducted from October 1, 1978, through March 31, 1979, to minimize seasonal effects and to enable use of all stored feeds.

All farms were visited at least twice per month during the trial. During these visits, feed samples and feed intake data were obtained. Samples were collected from several locations along the feed bunks shortly after feeding. Feed intake was estimated from actual feed weights where scales were used or from weighing the feed from measured sections of the feed bunk before animals were allowed to eat.

Records of movement of cows between groups were also recorded at this time. Production records of individual cows were eliminated if they had not been fed the current diet for at least 2 weeks before DHI testing.

In the laboratory the feeds were subsampled for dry matter determination and the remainder was frozen. All dry matter determinations were made after drying for 72 hours at 55° C; the samples were then ground and stored. At the end of each month, composite samples were made from the ground samples and taken to the Research Extension Analytical Laboratory.[2] There they were analyzed for crude protein (automated Kjeldahl), acid detergent fiber (13), and minerals (P, K, Ca, Mg, Fe, Cu, and Zn) using a Jarrel Ash Atom Counter Spectrograph. Upon receipt of the results of the feed analyses, samples were returned to the laboratory for ether extract analysis (Soxhlet extraction). One copy of the feed analysis report was sent to the county Extension agent for his review, a second copy was kept at the OARDC for this study, and a third copy was given to the dairyman with appropriate comments concerning his feeding program.

Milk production data from official Ohio Dairy Herd Improvement records were utilized. Milk testers and laboratory personnel were informed of the project objectives and requested to sample all the experimental herds within a short period of time each month.

Data from the monthly DHI cow listings were inspected for errors before inclusion in the data set. Records where sickness or abnormalities were noted were eliminated. Records between 21 and 305 days of lactation were included in the data set.

One month before the start of the trial, all farms were visited and feed samples were taken. Based on analysis in the Ration Evaluation Program, diets were balanced to meet National Research Council (NRC) requirements (9). Crude protein in the high production group was 16% to 17% and in the low production group was 13% to 14%.

A concerted effort was made to minimize nutrient variation throughout the trial.

Diets were fed *ad libitum* on all farms. Excluding hay, the diets were totally blended except on farms that offered additional grain in the milking parlor.

A protein supplement containing blended animal-vegetable fat[3] was developed to incorporate fat into the diets. The supplement was 60% soybean meal, 25% wheat middlings, and 15% blended animal-vegetable fat. It was mixed at one location and distributed to the farms through a local feed mill.

A modified paired design was used (Table 1) to compare the diet with the existing diet fed on each farm. Each farm served as its own control. The design, as shown in Table 1, was chosen because of its simplicity. Farms of similar size, and to some extent similar available roughage, were paired at the start of the trial in opposite treatment

[2]Research Extension Analytical Laboratory (REAL), Hayden Hall, Ohio Agricultural Research and Development Center, Wooster.

[3]Unifat-M-37, Jacob Stern & Sons Inc., Jenkintown, Pa.

TABLE 1.—Treatment Sequence of Experimental Farms.

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5 Farm 7	Farm 6 Farm 8
October 1 to November 30	Fat	Control	Fat	Control	Control	Fat
December 1 to January 31	Control	Fat	Control	Fat	Control	Fat
February 1 to March 31	Fat	Control	Control	Fat	Fat	Control

groups. After pairing, they were randomly assigned to one of the three pairs of treatment sequences. This procedure balanced the experiment and randomized period effects.

The experimental units were the monthly averages for all cows filling the criteria stated for each farm.

The model used is shown below.

$$Y_{ijk} = \mu + F_i + T_j + (FT)_{ij} + e_{ijk}$$

where: Y_{ijk} = observation on the k^{th} production group in the j^{th} treatment and the i^{th} farm

μ = population mean

F_i = effect of the i^{th} farm

T_j = effect of the j^{th} treatment

$(FT)_{ij}$ = effect of the j^{th} treatment in the i^{th} farm

e_{ijk} = random effect unique to the ijk^{th} record

The data were analyzed with a mixed model least-squares and maximum likelihood computer program (4). Holstein and Jersey herds were analyzed separately.

Further analyses were done to examine the response to added fat by animals of different production levels as determined by DHI extrapolated 305-day production records.

Feed changes from one 2-month feeding period to the next were made gradually during a 15-day period to avoid abrupt feed changes.

RESULTS AND DISCUSSION

Average daily feed intakes of cows in the Holstein herds are presented in Tables 2 through 7; Jersey herds in Tables 8 and 9. Estimated dry matter intakes were obtained from the Ohio Livestock Ration Evaluation Program. In this system, known amounts of grains, hays, and wherever possible silages, were used to estimate total dry matter consumption, based on estimated body weights and milk production.

Production from farm 1, period one, are not included in the final analysis due to nonadherence to the recommended feeding program. Therefore, the feed intake data for this period on farm 1 are estimates. Changes were made in the feeding program on farms 2, 4, and 5 during the trial, due either to insufficient amounts of forage or because of need to balance protein levels. All other farms were consistent in feeding with the outlined program throughout the trial.

Estimated feed intakes of Jerseys (Tables 8 and 9) were adjusted from the computer estimates obtained for the silage intakes. The daily forage intakes were lowered to approximately 1.2% of body weight.

Feed composition data are presented in Tables 10 through 15 for Holstein farms and in Tables 16 and 17 for Jersey farms. The data are the averages of all samples taken during each period.

A complete mixed ration was fed in the bunk on farms 2 through 6. Feedstuffs were mixed through a series of conveyors on farms 1 and 8. As feed mixing was not uniform on farm 8, the feed ingredients were sampled and analyzed separately.

In all cases where long hay was fed, the average intake per cow is given. This was calculated by dividing the total daily amount of hay fed by the number of cows in the group. These are, however, not necessarily accurate values due to the large amount of individual variation in forage preference that may have occurred (2).

Individual cow consumption of dry matter, crude protein, acid detergent fiber, ether extract, and calcium for each time period is presented in Tables 18 and 19.

Hay was included in the ration on farm 3, period 3, which raised the fiber content of the diet.

There was a general trend by cows in the high production groups to consume less fiber (percent of DM) when fed the high-fat ration (Table 18). This was due in part to normal variations in feedstuffs, and in part to a small increase in the amount of concentrate fed with the high-fat rations. Many of the dairymen used soybean meal (44% crude protein) as the protein supplement. The high-fat protein supplement was not as high in protein content (30% crude protein) as the soybean meal due to the addition of fat (15%) and wheat middlings (25%). Therefore, a greater amount of the high-fat supplement was fed to maintain equal intakes of protein.

A general tendency toward increased fiber intake during periods when the high-fat supplement was fed was apparent in the low production groups (Table 19). Protein was not a limiting factor when balancing the diets in these groups.

The results of acid detergent fiber analysis in Tables 18 and 19 do not include the contribution of fiber from the concentrates, since acid detergent fiber analyses were not done on these feeds.

The contribution of fiber from the grains, estimated from standard table values, increased the acid detergent fiber content of the diet by 1.5% to 2.5%, thus bringing these values to more than the recommended 21% of total dry matter fed.

The higher ether extract values of the high-fat rations reflect the addition of the high-fat supplements. The difference in fat content between control and high-fat rations was approximately 3% of the total dry matter. This amounted to an addition of 0.50 to 0.75 kg of fat per cow per day in the high production groups and slightly less in the lower producing groups. The variability in difference between control and added fat among farms is attributed to a slightly different amount of fat supplement added to each ration, which depended on the amount of protein supplement needed to balance the rations.

There were no significant differences in total daily dry matter intake between cows fed high or low fat feeds. However, due to the nature of the study, using group fed animals in free stall housing systems, small differences in total daily dry matter intake could not have been observed.

Consumption of crude protein and calcium was similar throughout the trial among groups within farms.

Overall acceptability and palatability of the feed were not problems.

The production records of all cows on each farm that satisfied the criteria previously established were averaged. The data for Holstein cows, farms 1 through 6, represent the means of 1743 and 861 records for the high and low production groups respectively. The data for Jersey cows, farms 7 and 8, represent 593 and 337 records for the high and low production groups.

Production data for each farm by month and by group are presented in Appendix Tables I and II.

The results of the second half of period 3 for farm 6 were unavailable because of liquidation of the herd due to problems not associated with the trial.

The high producing Holstein cows fed high fat produced significantly more milk (1.4 kg/day). Milk production increased from 24.9 to 26.3 kg/day ($P < .05$) (Table 20). Milk fat percent decreased significantly in the high fat groups from 3.7% to 3.5% for the control and high-fat feeds respectively ($P < .01$).

In the low producing groups, there were no differences in milk production caused by the rations. However, there was a significant difference ($P < .01$) in milk fat percent (4.0% vs. 3.8%) between the control and high fat groups (Table 21).

The increase observed in milk production is similar to other reported values (8, 10, 14), reflecting the increased energy value of the diet. Based on the National Research Council (NRC) (9) feed composition tables, the high-fat diets fed during the trial increased the net energy for lactation by 2.6 to 3.9 megacalories per cow per day.

A decrease in milk fat percent was reported by Wrenn *et al.* (14), who fed 10% of the concentrate as unprotected tallow. The ether extract percent of the total diet was increased by 5%, similar to levels in this study.

The only difference found in the Jersey herds was a decrease in milk production of cows fed the high-fat rations in the low production group, from 13.4 to 12.4 kg ($P < .01$). These data are presented in Tables 22 and 23. The larger variation between farms and smaller numbers of animals limited sensitivity of measuring differences between diets on these farms.

Although it has been reported that adding fat to dairy rations will reduce the concentration of milk protein (8, 11), no differences in milk protein concentration were found in any group in this study. In a review of feeding effects on milk protein concentration, Emery (3) pointed out that there is only a small effect of dietary protein on the concentration of milk protein. He also showed that feeding more energy, more protein, or less fiber causes increases in the concentration of milk protein. He concluded that the extra energy must be in the form of carbohydrate or other material that is capable of increasing blood glucose in order to increase milk protein. He further concluded that the addition of 4% to 12% oil or fat in any form will reduce the concentration of milk protein 0.1% to 0.3%. This was not observed in other research reported by Palmquist and Conrad (10), nor was it observed in this study. Milk protein depression may have occurred if the levels of added fat had been higher in this experiment.

When average production data for all farms were converted to 3.5% fat-corrected milk (Table 24), small non-significant differences favoring the high-fat feed were generally observed. The increased milk production of cows fed the high-fat feeds was offset by the decrease in milk fat content. This decrease in milk fat could possibly have been prevented if the fiber content of the diets had been increased as intended, as was previously shown by Palmquist and Conrad (10). It is also possible that the fat changed fiber digestibility and rumen fermentation patterns.

Another factor that could have changed the outcome of the study was the introduction of wheat middlings into the high-fat ration. Wheat middlings is a soluble form of carbohydrate and may have also significantly changed the pattern of rumen fermentation. Soluble carbohydrates in large amounts will usually lower the acetic to propionic acid ratio in the rumen by increasing the amount of propionic acid produced, and thus lower milk fat percent.

The results indicate that added energy in the form of fat is beneficial to high producing cows. No correlations were found between age of animal, lactation number or extrapolated 305-day milk production (level within the high and low production groups), and response to the high-fat feed.

Under some conditions the feeding of cows in large experimental groups may be preferable to feeding them individually. That was the case in the current study where the major objective was to obtain individual milk production of a large number of cows fed high-fat rations in order to evaluate small differences in milk production. While the experimental arrangement used allowed for the reduction of the standard error associated with differences among cows, a greater experimental error due to sampling was encountered since the DHI program allows sampling only at monthly intervals. A much larger number of replications would have reduced this error. The results associated with the larger population of animals, the Holsteins, were statistically significant while the results associated with the smaller population of animals, the Jerseys, were not. This demonstrates the importance of large numbers of cows when conducting a field trial based on DHI records.

The modified switchback design used in this study proved to be a strong statistical tool for evaluating the small differences associated with the treatments.

TABLE 2.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 1.*

Group 1—High Production		Period 1 (kg/day)	Period 2 & 3 (kg/day)
Legume/Grass Hay—Second Cutting		2.4	2.2
Legume Silage		6.5	6.4
Corn Silage		1.7	2.0
High Moisture Ground Ear Corn		3.2	3.2
Bunk Grain		4.5	4.5
Parlor Grain		1.6	1.6
	TOTAL	19.9	19.9

Group 2—Low Production		Period 1 (kg/day)	Period 2 & 3 (kg/day)
Legume/Grass Hay—Second Cutting		1.6	2.1
Legume Silage		2.9	2.4
Corn Silage		3.5	3.5
High Moisture Ground Ear Corn		2.7	2.7
Bunk Grain		2.4	2.4
Parlor Grain		1.6	1.6
	TOTAL	14.7	14.7

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 3.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 2.*

Group 1—High Production		Period 1 & 2 (kg/day)	Period 3 (kg/day)
Legume/Grass Silage		7.7	4.4
Corn Silage		2.4	2.4
High Moisture Ground Ear Corn		5.8	5.8
Bunk Grain		2.8	2.8
Legume Hay		0.0	3.3
	TOTAL	18.7	18.7

Group 2—Low Production		Period 1 & 2 (kg/day)	Period 3 (kg/day)
Legume/Grass Silage		5.3	3.7
Corn Silage		4.1	4.1
High Moisture Ground Ear Corn		3.7	3.7
Bunk Grain		2.4	2.4
Legume Hay		0.0	1.6
	TOTAL	15.5	15.5

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 4.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 3.*

Group 1—High Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		2.7
Legume/Grass Silage		5.2
Corn Silage		2.7
Bunk Grain		4.9
Parlor Grain		4.9
	TOTAL	20.4

Group 2—Low Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		2.7
Legume/Grass Silage		6.3
Corn Silage		3.7
Parlor Grain		4.9
	TOTAL	17.6

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 5.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 4.*

		Period (kg/day)	
Group 1—High Production		1	2 & 3
Legume/Grass Hay		3.2	3.1
Corn Silage		9.2	8.9
Bunk Grain		1.8	2.2
Parlor Grain		5.4	5.4
	TOTAL	19.6	19.6

		Period (kg/day)	
Group 1—High Production		1	2 & 3
Legume/Grass Hay		2.4	2.4
Corn Silage		9.7	9.5
Bunk Grain		0.4	0.4
Parlor Grain		4.0	4.0
	TOTAL	16.5	16.3

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 6.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 5.*

Group 1—High Production		Period 1 & 2 (kg/day)	Period 3 (kg/day)
Legume/Grass Hay		4.1	4.0
Corn Silage		8.3	8.0
Grain		5.7	5.7
Supplement Grain		1.6	2.0
	TOTAL	19.7	19.7

Group 2—Low Production		Period 1 & 2 (kg/day)	Period 3 (kg/day)
Legume/Grass Hay		3.8	3.8
Corn Silage		8.3	8.3
Grain		5.7	5.3
	TOTAL	17.8	17.4

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 7.—Estimated Average Dry Matter Intake of Cows on Holstein Farm 6.*

Group 1—High Production		Period 1-3 (kg/day)
Legume/Grass Hay		2.0
Legume/Grass Silage		8.2
Corn Silage		2.1
Bunk Grain		4.6
Parlor Grain		3.9
	TOTAL	20.8

Group 2—Low Production		Period 1-3 (kg/day)
Legume/Grass Hay		2.0
Legume/Grass Silage		4.5
Corn Silage		4.7
Bunk Grain		3.8
Parlor Grain		1.5
	TOTAL	16.5

*Based on actual hay and grain intakes and computer estimated silage intake.

TABLE 8.—Estimated Average Dry Matter Intake of Cows on Jersey Farm 1.*

Group 1—High Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		3.2
Corn Silage		5.5
Parlor Grain		9.1
	TOTAL	17.8

Group 2—Low Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		2.0
Corn Silage		5.5
Parlor Grain		5.5
	TOTAL	13.0

*Based on actual hay and grain intakes and adjusted computer estimated silage intake.

TABLE 9.—Estimated Average Dry Matter Intake of Cows on Jersey Farm 2.*

Group 1—High Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		2.0
Legume Silage		4.4
Corn Silage		2.6
Bunk Grain		3.6
Parlor Grain		4.1
	TOTAL	16.7

Group 2—Low Production		Period 1-3 (kg/day)
Legume/Grass Hay—Second Cutting		2.0
Legume Silage		5.3
Corn Silage		2.5
Parlor Grain		4.1
	TOTAL	13.9

*Based on actual hay and grain intakes and adjusted computer estimated silage intake.

TABLE 10.—Mean Composition of Feedstuffs on Holstein Farm 1.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
High Bunk Mix*	60.2	18.9	21.6	8.03	0.57	0.48	1.91	0.24
Low Bunk Mix†	47.2	13.7	26.1	5.35	0.39	0.32	1.61	0.20
Parlor Grain	91.5	25.8	‡	9.30	1.03	0.36	1.23	0.24
Hay	90.2	17.7	31.8	1.31	0.73	0.38	2.59	0.35
Period 2								
High Bunk Mix	58.5	16.1	33.8	2.98	0.76	0.35	2.29	0.35
Low Bunk Mix	52.2	13.1	22.8	2.39	0.44	0.32	1.45	0.25
Parlor Grain	85.7	23.8	‡	3.21	1.03	0.54	1.24	0.28
Hay	90.0	16.4	30.4	0.89	0.92	0.38	2.87	0.39
Period 3								
High Bunk Mix	43.7	14.7	29.2	6.85	0.68	0.42	1.81	0.24
Low Bunk Mix	48.0	12.5	28.7	5.63	0.45	0.33	1.79	0.23
Parlor Grain	87.1	19.5	‡	9.93	0.42	0.64	1.68	0.32
Hay	87.7	13.4	33.4	1.34	0.68	0.20	2.75	0.27

*Mixed feed for high production group.
†Mixed feed for low production group.
‡Not determined.

TABLE 11.—Mean Composition of Feedstuffs on Holstein Farm 2.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
High Bunk Mix*	63.3	19.5	15.1	3.56	0.78	0.55	1.14	0.32
Low Bunk Mix†	54.6	17.6	23.3	3.10	0.85	0.38	1.49	0.35
Period 2								
High Bunk Mix	61.3	18.3	18.9	5.41	0.81	0.40	1.43	0.28
Low Bunk Mix	58.7	17.9	21.1	4.33	0.89	0.34	1.68	0.33
Period 3								
High Bunk Mix	58.4	19.8	19.9	3.15	0.98	0.34	1.37	0.28
Low Bunk Mix	52.0	16.9	20.7	2.82	0.56	0.40	1.24	0.25
Hay	93.5	12.6	28.7	2.10	0.74	0.31	2.51	0.23

*Mixed feed for high production group.
†Mixed feed for low production group.

TABLE 12.—Mean Composition of Feedstuffs on Holstein Farm 3.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
High Bunk Mix*	45.6	15.0	21.4	5.81	0.76	0.48	1.50	0.29
Low Bunk Mix†	41.1	14.5	31.8	4.03	0.95	0.29	2.46	0.27
Parlor Grain	89.6	15.8	‡	4.63	0.41	0.51	0.76	0.20
Hay	88.8	15.9	31.2	1.61	0.91	0.28	3.13	0.25
Period 2								
High Bunk Mix	47.2	16.6	25.0	3.60	0.83	0.43	1.74	0.28
Low Bunk Mix	39.9	14.0	31.8	4.11	0.65	0.22	2.27	0.28
Parlor Grain	85.7	14.7	‡	2.25	0.37	0.49	0.66	0.19
Hay	89.0	15.2	34.9	1.04	1.05	0.26	2.71	0.28
Period 3								
High Bunk Mix	49.9	16.6	26.6	4.10	0.93	0.35	2.33	0.23
Low Bunk Mix	43.6	17.6	33.0	4.07	1.14	0.27	2.51	0.30
Parlor Grain	88.0	14.3	‡	2.62	0.62	0.60	0.55	0.22
Hay	90.0	18.2	32.1	1.42	1.14	0.28	3.12	0.27

*Mixed feed for high production group.
†Mixed feed for low production group.
‡Not determined.

TABLE 13.—Mean Composition of Feedstuffs on Holstein Farm 4.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
High Bunk Mix*	37.9	12.6	23.0	2.65	0.92	0.53	1.31	0.23
Low Bunk Mix†	36.0	8.7	21.5	2.11	1.20	0.48	1.11	0.22
Parlor Grain	88.4	19.4	‡	3.39	0.54	0.28	0.88	0.18
Hay	90.9	16.2	33.0	2.02	0.69	0.32	2.49	0.25
Period 2								
High Bunk Mix	36.6	11.3	20.7	3.71	1.03	0.55	1.28	0.22
Low Bunk Mix	33.2	8.5	25.7	2.64	0.79	0.38	1.27	0.21
Parlor Grain	86.8	21.5	‡	10.43	0.80	0.43	1.13	0.25
Hay	88.2	17.4	31.0	2.21	1.01	0.35	2.84	0.22
Period 3								
High Bunk Mix	37.1	14.3	21.1	4.18	0.78	0.63	1.30	0.24
Low Bunk Mix	33.4	9.3	23.7	3.53	0.84	0.52	1.26	0.22
Parlor Grain	86.8	22.9	‡	9.98	0.87	0.52	1.12	0.22
Hay	87.7	19.0	31.6	2.52	1.18	0.37	3.08	0.30

*Mixed feed for high production group.
†Mixed feed for low production group.
‡Not determined.

TABLE 14.—Mean Composition of Feedstuffs on Holstein Farm 5.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
Bunk Mix*	46.5	12.4	19.8	2.67	0.81	0.35	0.94	0.22
Bunk Grain	91.8	49.0	†	2.96	0.41	0.72	2.18	0.37
Hay	91.3	17.6	30.8	1.42	0.89	0.29	2.48	0.28
Period 2								
Bunk Mix	44.1	12.4	19.3	3.41	0.80	0.33	0.91	0.20
Bunk Grain	87.4	50.9	†	3.31	0.33	0.57	2.37	0.35
Hay	91.7	15.6	33.4	0.87	0.80	0.35	2.79	0.28
Period 3								
Bunk Mix	52.5	12.1	17.9	5.53	0.76	0.39	0.92	0.24
Bunk Grain	92.2	38.3	†	15.56	0.28	0.59	1.73	0.31
Hay	90.9	17.7	30.4	6.21	1.06	0.31	2.46	0.33

*Varying amounts of these feeds were used to make up the high and low production group rations.
†Not determined.

TABLE 15.—Mean Composition of Feedstuffs on Holstein Farm 6.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
High Bunk Mix*	45.0	15.9	29.0	4.21	0.85	0.35	2.97	0.28
Low Bunk Mix†	39.0	13.1	29.6	4.08	0.61	0.27	1.93	0.24
Parlor Grain	85.6	18.2	‡	6.22	0.63	0.48	1.07	0.21
Hay	90.7	16.0	32.4	2.01	0.55	0.29	2.82	0.33
Period 2								
High Bunk Mix	44.5	16.3	27.7	4.19	0.81	0.43	2.19	0.24
Low Bunk Mix	33.6	12.8	26.7	3.97	0.52	0.34	1.59	0.24
Parlor Grain	86.0	16.4	‡	7.02	0.52	0.41	0.76	0.19
Hay	85.7	16.0	33.5	1.94	1.31	0.31	3.95	0.42
Period 3								
High Bunk Mix	35.2	15.6	31.8	3.17	0.86	0.37	2.43	0.25
Low Bunk Mix	34.2	12.7	30.5	3.41	0.54	0.30	1.69	0.24
Parlor Grain	85.8	16.0	‡	4.47	0.74	0.51	0.94	0.16
Hay	90.2	15.4	35.9	1.57	0.71	0.33	3.34	0.22

*Mixed feed for high production group.
†Mixed feed for low production group.
‡Not determined.

TABLE 16.—Mean Composition of Feedstuffs on Jersey Farm 1.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
Corn Silage*	31.0	8.4	26.8	2.08	0.34	0.24	1.18	0.20
Grain	90.8	22.3	†	3.06	1.02	0.48	1.12	0.28
Hay	91.2	18.5	30.7	2.02	0.95	0.31	2.87	0.23
Period 2								
Corn Silage	32.6	8.2	26.0	1.50	0.26	0.22	1.02	0.19
Grain	87.7	20.8	†	3.11	1.14	0.51	1.05	0.35
Hay	90.4	16.4	40.5	1.81	0.69	0.37	2.68	0.29
Period 3								
Corn Silage	31.1	8.0	27.4	1.61	0.33	0.24	1.24	0.17
Grain	89.3	22.0	†	5.91	1.18	0.64	1.26	0.36
Hay	91.4	16.3	31.8	1.57	0.86	0.31	2.69	0.21

*Varying amounts of these feeds were used to make up the high and low production group rations.
†Not determined.

TABLE 17.—Mean Composition of Feedstuffs on Jersey Farm 2.

	Dry Matter	Crude Protein	Acid Detergent Fiber	Ether Extract	Ca	P	K	Mg
	%	Percent of Dry Matter						
Period 1								
Haylage*	39.9	17.8	33.2	4.82	0.83	0.29	2.69	0.23
Corn Silage	36.2	7.2	23.6	2.44	0.24	0.24	1.21	0.17
Parlor Grain	89.9	18.3	†	7.89	0.97	0.51	0.91	0.20
Bunk Grain	90.6	19.8	†	8.32	0.66	0.65	1.01	0.20
Hay	91.2	16.9	27.6	2.76	0.78	0.27	2.23	0.23
Period 2								
Haylage	35.1	18.3	34.9	3.37	0.89	0.27	3.16	0.22
Corn Silage	34.5	7.4	23.8	2.24	0.33	0.28	1.09	0.21
Parlor Grain	89.7	21.0	†	9.44	0.70	0.45	0.96	0.24
Bunk Grain	90.4	21.6	†	10.30	0.57	0.89	0.87	0.22
Hay	93.3	18.8	26.2	2.40	1.02	0.22	3.19	0.29
Period 3								
Haylage	40.8	17.3	37.4	3.70	0.88	0.31	3.28	0.22
Corn Silage	44.7	7.7	25.0	3.11	0.41	0.21	1.16	0.19
Parlor Grain	89.0	19.4	†	2.72	1.31	0.51	0.87	0.19
Bunk Grain	89.2	20.8	†	4.73	0.97	0.77	1.03	0.19
Hay	89.8	18.3	32.1	1.87	0.92	0.26	3.63	0.21

*Varying amounts of these feeds were used to make up the high and low production group rations.
†Not determined.

TABLE 18.—Summary of Total Nutrient Intake of Cows in High Production Groups.

	Period	Treatment*	Dry Matter†	Crude Protein	Ether Extract	Acid Detergent Fiber‡	Calcium
Holstein			(Kg)	Percent of Dry Matter			
Farm 1	1	F	19.9	19.1	7.3	21.1	0.65
	2	C	19.9	16.6	2.8	30.7	0.80
	3	F	19.9	15.1	6.5	27.3	0.65
Farm 2	1	C	18.7	19.5	3.6	15.1	0.78
	2	F	18.7	18.3	5.4	18.9	0.81
	3	C	18.7	18.2	3.0	21.4	0.91
Farm 3	1	F	20.4	15.2	5.0	17.5	0.68
	2	C	20.4	16.2	2.9	20.3	0.83
	3	C	20.4	16.2	3.4	20.9	0.88
Farm 4	1	C	19.6	15.9	2.9	18.3	0.82
	2	F	19.6	15.9	5.3	16.7	0.96
	3	F	19.6	17.0	5.5	16.9	0.86
Farm 5	1	C	19.7	16.2	2.2	16.5	0.66
	2	C	19.7	16.2	2.7	16.4	0.66
	3	F	19.7	16.2	5.7	15.3	0.66
Farm 6	1	F	20.8	16.3	4.4	23.9	0.77
	2	F	20.8	16.3	4.5	23.0	0.82
	3	C	20.8	15.9	3.2	26.3	0.82
Jersey							
Farm 1	1	C	19.8	18.2	2.5	15.1	0.78
	2	C	19.8	15.2	2.3	16.4	0.71
	3	F	19.8	15.7	3.6	15.6	0.81
Farm 2	1	F	18.7	16.6	5.6	17.6	0.75
	2	F	18.7	18.2	5.7	18.1	0.75
	3	C	18.7	17.1	3.4	19.2	0.90

*C=control ration, F=high fat ration.
†Based on actual hay and grain intakes and computer estimated silage intake.
‡Does not include contribution from grains.

TABLE 19.—Summary of Total Nutrient Intake of Cows in Low Production Groups.

	Period	Treatment*	Dry Matter†	Crude Protein	Ether Extract	Acid Detergent Fiber‡	Calcium
			(Kg)	Percent of Dry Matter			
Holstein							
Farm 1	1	F	14.7	15.6	5.4	23.9	0.48
	2	C	14.7	15.0	2.2	21.4	0.61
	3	F	14.7	13.6	5.5	26.2	0.48
Farm 2	1	C	15.5	17.4	3.1	23.4	0.84
	2	F	15.5	18.1	4.3	21.1	0.90
	3	C	15.5	16.1	2.7	21.5	0.58
Farm 3	1	F	17.6	15.3	3.8	22.8	0.79
	2	C	17.6	14.2	3.1	23.4	0.68
	3	C	17.6	16.5	3.3	23.6	0.96
Farm 4	1	C	16.5	12.8	2.5	19.3	0.99
	2	F	16.3	13.1	4.4	20.2	0.88
	3	F	16.3	13.9	4.9	19.1	0.84
Farm 5	1	C	17.8	13.5	2.4	22.1	0.78
	2	C	17.8	13.0	2.7	22.3	0.78
	3	F	17.4	13.5	5.7	19.0	0.83
Farm 6	1	F	16.5	13.9	4.0	27.2	0.61
	2	F	16.5	13.3	4.1	25.1	0.67
	3	C	16.5	13.3	3.0	28.4	0.55
Jersey							
Farm 1	1	C	14.0	15.7	2.4	16.8	0.71
	2	C	14.0	14.3	2.2	17.9	0.64
	3	F	14.0	15.0	3.3	17.3	0.71
Farm 2	1	F	15.9	16.4	5.0	23.6	0.75
	2	F	15.9	16.9	4.7	23.1	0.75
	3	C	15.9	16.6	3.1	25.1	0.94

*C=control ration, F=high fat ration.
†Based on actual hay and grain intakes and computer estimated silage intake.
‡Does not include contribution from grains.

TABLE 20.—Mean Milk Production of High Production Groups, Holstein Farms.

	Treatment*	Least-Squares Mean	SEM	P
Milk (kg/day)	C	24.9	0.40	0.017
	F	26.3	0.38	
Fat (%)	C	3.72	0.040	0.0023
	F	3.53	0.038	
Protein (%)	C	3.19	0.034	0.28
	F	3.14	0.032	

*C=control, F=high fat.

TABLE 21.—Mean Milk Production of Low Production Groups, Holstein Farms.

	Treatment*	Least-Squares Mean	SEM	P
Milk (kg/day)	C	15.8	0.48	0.16
	F	16.8	0.46	
Fat (%)	C	3.99	0.054	0.064
	F	3.85	0.052	
Protein (%)	C	3.42	0.046	0.84
	F	3.41	0.044	

*C=control, F=high fat.

TABLE 22.—Mean Milk Production of High Production Groups, Jersey Farms.

	Treatment*	Least-Squares Mean	SEM	P
Milk (kg/day)	C	20.5	0.33	0.70
	F	20.7	0.33	
Fat (%)	C	5.11	0.079	0.38
	F	5.21	0.079	
Protein (%)	C	3.99	0.094	0.14
	F	3.77	0.094	

*C=control, F=high fat.

TABLE 23.—Mean Milk Production of Low Production Groups, Jersey Farms.

	Treatment*	Least-Squares Mean	SEM	P
Milk (kg/day)	C	13.4	0.17	0.0037
	F	12.4	0.17	
Fat (%)	C	5.61	0.12	0.34
	F	5.44	0.12	
Protein (%)	C	4.39	0.11	0.11
	F	4.10	0.11	

*C=control, F=high fat.

TABLE 24.—Mean 3.5% Fat-corrected Milk Production.*

	High Producers		Low Producers	
	Control	High-Fat	Control	High-Fat
		(kg/day)		
Holstein				
Farms 1-6	25.6	26.3	17.1	17.6
Jersey				
Farms 1 and 2	25.9	26.4	18.0	16.2

*Gaines, W. L. 1928. The Energy Basis of Measuring Milk Yield in Dairy Cows. Illinois Agri. Exp. Sta., Bull. 308, p. 403.

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APPENDIX TABLE I.—Average Production of Cows in High Groups.

	Period	Treatment*	Milk	Fat	Protein
Holstein			(kg/day)	(%)	(%)
Farm 1	1†	F	22.3	2.99	3.02
	2†	F	22.8	2.83	3.32
	3	C	22.8	3.78	3.23
	4	C	22.2	3.82	2.94
	5	F	20.9	3.65	3.30
	6	F	22.8	3.51	3.16
Farm 2	1	C	29.4	3.60	3.14
	2	C	30.9	3.33	3.23
	3	F	29.2	3.57	2.90
	4	F	30.0	3.70	3.22
	5	C	26.0	3.32	3.20
	6	C	29.1	3.30	3.00
Farm 3	1	F	28.9	3.81	3.12
	2	F	28.0	3.57	3.21
	3	C	28.9	3.85	3.19
	4	C	28.5	3.86	3.39
	5	C	26.3	3.87	3.35
	6	C	25.0	3.91	3.23
Farm 4	1	C	22.3	3.68	3.30
	2	C	22.4	3.87	3.46
	3	F	25.8	3.63	3.02
	4	F	28.0	3.07	3.19
	5	F	29.4	3.00	2.94
	6	F	26.9	3.29	2.95
Farm 5	1	C	24.0	3.69	3.01
	2	C	25.3	3.75	3.26
	3	C	26.0	3.70	3.05
	4	C	26.5	3.80	2.89
	5	F	28.3	3.42	3.35
	6	F	28.5	3.56	3.23
Farm 6	1	F	19.7	3.61	3.00
	2	F	22.8	3.37	3.09
	3	F	22.5	3.66	2.94
	4	F	23.2	3.57	3.13
	5	C	22.9	3.77	3.17
	6‡	C			
Jersey					
Farm 1	1	C	19.4	4.58	3.66
	2	C	20.0	4.96	4.25
	3	C	19.8	5.13	3.90
	4	C	20.1	5.16	4.29
	5	F	21.0	5.19	3.83
	6	F	23.4	5.14	3.72
Farm 2	1	F	19.7	5.24	3.55
	2	F	18.9	5.17	3.91
	3	F	18.8	5.22	3.70
	4	F	19.8	5.41	3.93
	5	C	20.6	5.36	3.99
	6	C	21.9	5.16	3.92

*C=control diet, F=high fat diet.
†Not included in statistical analysis.
‡Missing data.

APPENDIX TABLE II.—Average Production of Cows in Low Groups.

	Period	Treatment*	Milk	Fat	Protein
Holstein			(kg/day)	(%)	(%)
Farm 1	1†	F	12.9	3.65	3.34
	2†	F	14.7	3.17	3.66
	3	C	15.6	3.97	3.43
	4	C	14.3	3.83	3.12
	5	F	13.9	4.08	3.52
	6	F	14.6	3.96	3.52
Farm 2	1	C	17.4	4.02	3.26
	2	C	17.9	4.13	3.62
	3	F	16.4	4.20	3.11
	4	F	17.3	4.06	3.46
	5	C	16.8	3.93	3.42
	6	C	18.3	3.71	3.27
Farm 3	1	F	20.8	3.84	3.28
	2	F	25.0	3.56	3.44
	3	C	21.0	3.89	3.25
	4	C	18.2	3.86	3.46
	5	C	15.1	3.79	3.38
	6	C	15.6	3.91	3.23
Farm 4	1	C	16.3	3.94	3.44
	2	C	16.2	4.03	3.65
	3	F	17.5	3.94	3.27
	4	F	16.5	3.39	3.50
	5	F	16.2	3.22	3.27
	6	F	15.6	3.53	3.21
Farm 5	1	C	13.3	4.20	3.41
	2	C	16.4	4.05	3.50
	3	C	18.5	4.15	3.19
	4	C	18.9	4.05	3.04
	5	F	18.8	3.89	3.54
	6	F	15.6	3.75	3.56
Farm 6	1	F	12.1	4.11	3.31
	2	F	13.7	3.47	3.38
	3	F	12.2	3.81	3.29
	4	F	14.0	4.20	3.74
	5	C	11.7	4.16	3.71
	6‡	C			
Jersey					
Farm 1	1	C	13.5	5.26	3.96
	2	C	12.7	5.52	4.43
	3	C	13.2	5.58	4.23
	4	C	12.8	5.59	4.68
	5	F	12.1	5.65	4.11
	6	F	12.7	5.63	4.15
Farm 2	1	F	12.3	4.70	3.76
	2	F	12.2	5.25	4.14
	3	F	12.1	5.50	3.93
	4	F	12.7	5.52	4.43
	5	C	13.2	5.91	4.57
	6	C	14.1	5.55	4.35

*C=control diet, F=high fat diet.
†Not included in statistical analysis.
‡Missing data.

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of research at the Ohio Agricultural Research and Development Center. All Ohioans benefit from this product.

Ohio's farm families benefit from the results of agricultural research translated into increased earnings and improved living conditions. So do the families of the thousands of workers employed in the firms making up the state's agribusiness complex.

But the greatest benefits of agricultural research flow to the millions of Ohio consumers. They enjoy the end products of agricultural science—the world's most wholesome and nutritious food, attractive lawns, beautiful ornamental plants, and hundreds of consumer products containing ingredients originating on the farm, in the greenhouse and nursery, or in the forest.

The Ohio Agricultural Experiment Station, as the Center was called for 83 years, was established at The Ohio State University, Columbus, in 1882. Ten years later, the Station was moved to its present location in Wayne County. In 1965, the Ohio General Assembly passed legislation changing the name to Ohio Agricultural Research and Development Center—a name which more accurately reflects the nature and scope of the Center's research program today.

Research at OARDC deals with the improvement of all agricultural production and marketing practices. It is concerned with the development of an agricultural product from germination of a seed or development of an embryo through to the consumer's dinner table. It is directed at improved human nutrition, family and child development, home management, and all other aspects of family life. It is geared to enhancing and preserving the quality of our environment.

Individuals and groups are welcome to visit the OARDC, to enjoy the attractive buildings, grounds, and arboretum, and to observe first hand research aimed at the goal of Better Living for All Ohioans!

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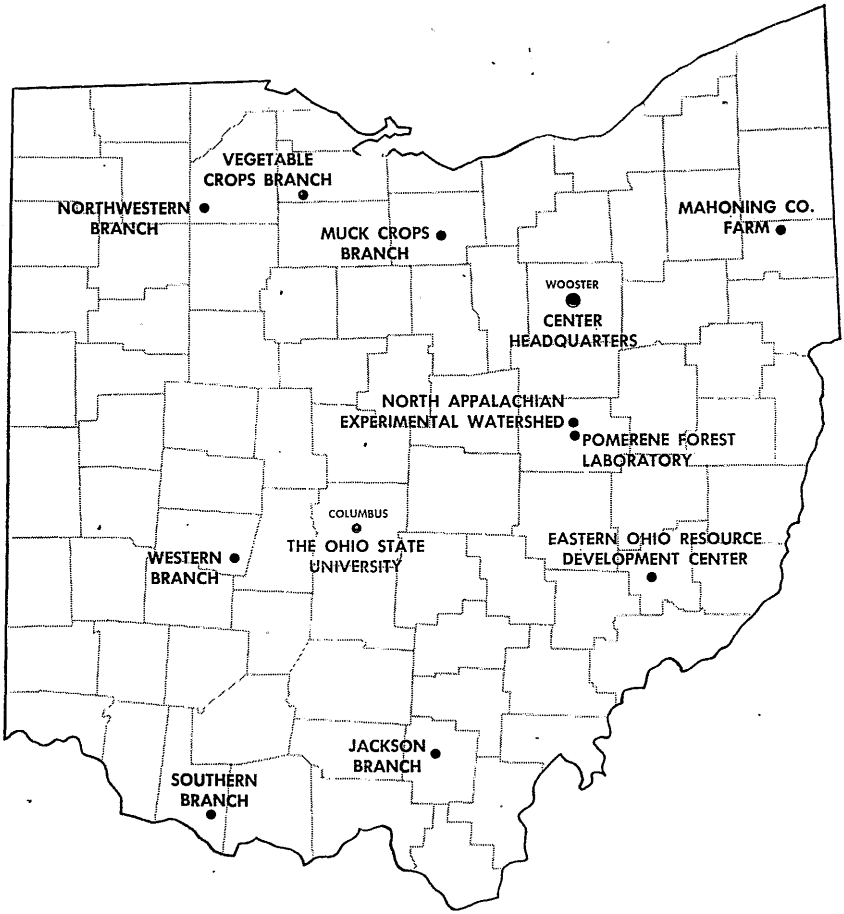

Ohio's major soil types and climatic conditions are represented at the Research Center's 12 locations.

Research is conducted by 15 departments on nearly 7,000 acres at Center headquarters in Wooster, eight branches, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Jackson Branch, Jackson, Jackson County: 502 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with the Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres